APPENDIX M

THE EFFECT OF STEPWISE ASCENT ON THE INCIDENCE OF DECOMPRESSION SICKNESS.

By

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REPORT

5th February, 1943.

for

Associate Committee on Aviation Medical Research
National Research Council, Canada.

from

No. 2 Clinical Investigation Unit, No. 2 I.T.S., RCAF., Regina.

Subject - The Effect of Stepwise Ascent on the Incidence of Decompression Sickness.

Author - A. M. Fraser, Squadron Leader.

Initiated by - Medical Officer i/c, No. 2 C.I.U.

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SUMMARY

Purpose The effect on incidence of decompression sickness of levelling off at moderate altitudes for a period before ascending to 35,000 feet was investigated for the purpose of providing information on the following questions:

(1) Does "silent bubble" formation in the body seriously interfere with denitrogenation, and if so, at what altitudes?

(2) Would flight at moderate altitudes in the early portion of a mission provide significant protection against decompression sickness during high altitude exposure later in the trip?

Scope Thirty-three men in a total of 360 man-runs were given one-hour flights at 10,000 feet, 20,000 feet or 27,500 feet prior to rapid ascent to 35,000 feet and the incidence of decompression sickness was compared with controls, on the same men. The oxygen supply in liters (N.T.P.) per minute was 4.2, 2.6 and 3.5 at 10,000 feet, 20,000 feet and 27,500 feet respectively. Alveolar nitrogen tension was greatest at 10,000 feet and least at 27,500 feet.

Conclusions 1. The man-runs with moderate or severe symptoms of decompression sickness were reduced from 45% in controls to 20% and 12% by levelling off for an hour at 20,000 feet and 10,000 feet respectively prior to ascent to 35,000 feet, and from 40% in controls to 28% by levelling off for an hour at 27,500 feet prior to ascent to 35,000 feet.

2. It is concluded that while considerable protection against decompression sickness is provided by stepwise ascent, "silent bubble" formation at 27,500 feet, and probably at 20,000 feet, reduces this protection

Recommendations 1. The protection against decompression sickness, provided by flight at symptom-free altitudes, and the effect of "silent bubble"

formation in decreasing this protection, should be considered in planning high operational flights.

2. It is recommended that further work be done on the protective effect of short periods of denitrogenation immediately prior to ascent.

Initial Distribution:

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INTRODUCTION

Flight at moderate altitudes (or pressure) for considerable periods, prior to ascent (or decompression) to high altitudes may occur under two conditions.

1. The prospective use of pressurized cabins in aircraft and the associated danger of puncture of these introduces a situation where the earlier part of the flight may be made at a moderate pressure prior to rapid decompression to the low pressure of high altitude if puncture occurs.

2. In long range bombing flights, freedom from exposure to enemy action during the earlier portion of the trip may permit lower flying than that required in the latter part of the mission.

In view of these probable operational conditions, an investigation into the effect of these on the incidence of decompression sickness appeared warranted.

Several factors might be expected to affect the incidence of decompression sickness under the conditions described above.

1. The slight reduction in atmospheric pressure during the early part of the flight mightin itself, by denitrogenation, decrease the incidence of decompression sickness on subsequent ascent to higher altitude.

2. If oxygen were used during this earlier part of the flight the denitrogenation process would be hastened.

3. The formation of bubbles in the body at altitudes below that at which symptoms occur, might be expected, on theoretical grounds, to retard the denitrogenation process locally. Bubble formation is possible, although very improbable, on ascent from sea level to 4,000 feet, since supersaturation of non-equilibrating tissues, with gases is present at this altitude. Symptoms of decompression sickness are rarely experienced below 25,000 feet, although Evelyn (1) has been able to detect free gas in the

joints radiologically following one hour's exposure to altitudes as low as 20,000 feet. In general it appears unlikely that bubbles are frequently formed by exposures below 15,000 feet. On this basis any possible effect of previously formed bubbles on incidence of decompression sickness following ascent to high altitude would be expected only in flights where levelling off occurred above 15,000 feet, prior to ascent to the final higher altitude.

4. The rapid decrease in pressure which may occur following puncture of a pressurized aircraft cabin may influence the incidence of decompression sickness. It has been found that practical variations in rates of ascent (15 to 60 minutes from sea level to 35,000 feet) have very little effect except that the onset of symptoms is more delayed following the more rapid ascent (2). However, no systematic work has been reported, on the effect of the rapid decompressions possible in pressure cabin puncture, upon the incidence of decompression sickness.

Evelyn (1) states that levelling off for two hours at 20,000 feet does not prevent symptoms on subsequent ascent to 30,000 feet, similarly he reports that levelling off at 30,000 feet for four hours does not prevent symptoms on subsequent ascent to 35,000 feet. It appears possible, that at these altitudes (20,000 feet and 30,000 feet) "silent bubble" formation may have interfered with denitrogenation. The oxygen flows employed at 20,000 feet and 30,000 feet were not stated. In this connection it must be noted that Evelyn's work was carried out at 900 feet above sea level whereas #2 Clinical Investigation Unit is 1900 feet above sea level.

The present investigation, because of the rapid ascent employed, simulates conditions in a slowly leaking pressurized aircraft, although the results are also believed to be applicable to high flights which are preceded by periods at a lower altitude, as described above.

METHODS

In this investigation the effect of levelling off at 10,000 feet and 20,000 feet was first studied and compared with a set of control flights. Because of the results obtained the investigation was extended to include a study of the effect of levelling off at 27,500 feet by comparison with another set of controls.

Thirty-three men were used as subjects in this study. They were selected for their high susceptibility to decompression sickness from 275 prospective aircrew. Three hundred and sixty man-runs, including controls, were made during the series.

In control runs the standard rate of ascent was employed, followed by a two-hour stay at 35,000 feet. In the experimental runs ascent was made at the standard rate up to either 10,000 feet, 20,000 feet or 27,500 feet, which altitude was maintained constant for an hour. Following this, ascent to 35,000 feet was made at maximal rate, this altitude being maintained for two hours. The standard rate of ascent, as used in this and most Canadian work, is 2,000 feet per minute to 20,000 feet; 1,000 feet per minute from 20,000 to 30,000 feet, and 500 feet per minute above 30,000 feet. The times

required for ascent to 35,000 feet following the one hour stay at 10,000 feet, 20,000 feet and 27,500 feet were 3½ minutes, 2 minutes and 1 minute respectively.

The R.C.A.F. oxygen assembly (reservoir type) was used throughout the runs, except for a few of the first flights in which the oronasal Boothby mask was used, due to unavailability of the former. During the one-hour stay at 10,000 feet, 20,000 feet and 27,500 feet the oxygen flows supplied per minute were 4.2 liters (N.T.P.), 2.6 liters (N.T.P.) and 3.5 liters (N.T.P.) respectively, while at 35,000 feet the flow used was 4.5 liters (N.T.P.) per minute. The high oxygen flow during the stays at 10,000 feet was designed to reduce the alveolar nitrogen tension to approximately that present during the flights at 20,000 feet, thus minimizing the variation in rates of denitrogenation and limiting the variables between the two types of runs to that of altitude. It was believed that the oxygen supply at 27,500 feet would lower the nitrogen tension further than that at 10,000 feet or 20,000 feet. Subsequent to the series of flights actual alveolar nitrogen determinations, using these oxygen flows, were made on several men at each of the three altitudes and gave results somewhat different than expected. The alveolar nitrogen tensions found in a very co-operative subject of average size were 205 mm. Hg., 114 mm. Hg., and 81 mm. Hg., at 10,000 feet, 20,000 feet and 27,500 feet respectively. These values are probably not at all representative of the absolute nitrogen tensions which actually occurred during the flights in the 35 men. Such values must necessarily vary with the depth and rate of respiration, with each mask, each Heidbrink orifice and with the degree of co-operation of the subject. It is believed however that the values above do indicate the relative alveolar nitrogen tensions which occurred at these altitudes and give a very approximate estimate of the absolute tensions which were present during the flights.

The incidence of decompression sickness at 35,000 feet, following one hour stays at 10,000 feet and at 20,000 feet were compared with the same set of controls and with each other. This was made possible by carrying out the three types of runs in rotation. These were done in a total of 187 man-runs on 22 of the men, and during most of the work the runs were made daily, so that a control, a 10,000 foot stepwise ascent run, and a 20,000 feet stepwise ascent run were each carried out every third day. In a few cases the runs were made at two day intervals, other types of runs being taken in the intervening days; the rotation described above was maintained, however. This rotation was adhered to in order to insure a more reliable comparison amongst the three types of runs, by avoiding errors due to acclimatization, or to natural changes in resistance. (See Appendix B for actual dates of the runs).

The flights which included a one-hour stay at 27,500 feet, were carried out later than those at 10,000 feet and 20,000 feet, and were made along with a separate set of controls. This group of runs was carried out on 22 of the men during two periods of 7 and 10 consecutive days, in a total of 173 man-runs. Controls were made on the first, fourth, seventh and tenth days. (See Appendix C for actual dates).

The men recorded their own symptoms in the chamber. These were reported as mild, moderate and severe and scored according to the technique described in Appendix A, a technique which has been adopted tentatively by this Unit.

OBSERVATIONS

Table I shows that the average symptom scores following the one-hour stays at 10,000 and 20,000 feet are reduced to 26% and 37% respectively of the average control score. It will be seen that these percentages are in approximately the same ratio as the percentage of runs with symptoms of moderate or severe degree which was reduced from 45% in controls to 20% and 12% in the 20,000 feet and 10,000 feet flights respectively. Amongst the average control scores there are nine values over 300, whereas there is only one in the 20,000 feet flights, and none in the 10,000 feet runs.

Table II shows the comparison between the scores of control runs and those following one-hour stays at 27,500 feet. It will be seen that the symptom score in the 27,500 feet flights is reduced to 73% of that of the controls. Again these percentages are in approximately the same ratio as the percentage of runs with symptoms of moderate or severe degree, which was reduced from 40% in controls to 28% in the 27,500 feet flights.

TABLE I

Effects of One-Hour Stays at 20,000 Feet and 10,000 Feet on Symptom Score

	Controls-2 Hours at 35,000 Feet		One Hour at 20,000 Ft. Two Hours at 35,000 Ft.		One Hour at 10,000 Ft. Two Hours at 35,000 Ft.	
Subject Number	Number of Flights	Average Symptom Score	Number of Flights	Average Symptom Score	Number of Flights	Average Symptom Score
1	2	296	2	80	2	0
2	2	305	2	105	2	0
3	2	72	2	52	2	0
4	2	25	2	0	2	0
5	2	42	2	180	2	40
6	2	24	2	42	1	0
7	3	41	3	0	3	0
8	3	832	3	0	3	66
9	3	321	3	250	3	0
10	3	334	3	176	3	202
11	3	614	2	31	3	257
12	4	378	3	192	3	23
13	4	562	3	440	3	280
14	4	426	3	0	3	31
15	3	85	3	0	3	23
16	4	467	3	131	3	90
17	4	6	3	49	3	0
18	3	298	3	27	3	0
19	4	190	3	0	3	0
20	4	217	3	184	3	86
21	4	0	3	46	3	238
22	4	231	3	144	3	171
TOTALS	69	5766	59	2129	59	1507
Average Score		262		97		68
% of Control Score		100		37		26
Runs With No Symptoms		35%		58%		71%
Runs With Mild Symptoms Only		20%		22%		17%
Runs With Moderate or Severe Symptoms		45%		20%		12%

TABLE II

Effect of One-Hour Stays at 27,500 Feet on Symptom Scores

(Controls) Two Hours at 35,000 Feet			One Hour at 27,500 Feet Two Hours at 35,000 Feet	
Subject Number	Number of Flights	Average Symptom Score	Number of Flights	Average Symptom Score
12	3	230	4	0
13	3	303	4	560
14	3	0	3	0
15	3	45	3	123
16	3	173	4	0
17	3	0	3	0
18	3	193	4	81
19	3	63	4	0
20	3	112	4	0
21	3	0	4	0
22	3	323	4	2
23	4	34	6	20
24	4	75	6	187
25	4	105	5	38
26	3	754	5	321
27	4	917	6	689
28	4	416	6	329
29	4	824	6	591
30	4	13	6	3
31	4	297	5	149
32	2	168	4	334
33	3	148	4	385
Totals	73	5193	100	3812
Average Score		236		173
Percent of Control Score		100%		73%
Runs With No Symptoms		46%		62%
Runs With Only Mild Symptoms		14%		9%
Runs With Moderate or Severe Symptoms		40%		28%

DISCUSSION

Either or both the factors of denitrogenation and rate of ascent must be responsible for the difference between the control scores and those following preliminary stays at 10,000 feet. Rapid rate of ascent is generally regarded as likely to increase symptoms of decompression sickness. Although variations in practical rates of ascent (15 to 60 minutes to 35,000 feet) result in no changes in incidence (2), a systematic study of the effect of the rapid ascents used in this investigation has not been made, to the writer's knowledge. It is assumed tentatively that the marked reduction in symptoms following rapid ascent to 35,000 feet, subsequent to the one-hour stays at 10,000 feet, is due to denitrogenation. The definite, although somewhat less marked, reduction in symptoms following the one-hour stays at 20,000 feet is likewise assumed to be due to the same cause. Although it is likely that general denitrogenation at 20,000 feet was greater than at 10,000 feet (see methods), symptoms were more frequent following flight at the former altitude. It is possible that this difference in incidence, which is of doubtful significance, is produced by bubble formation during the stay at 20,000 feet. Such bubble formation besides interfering with local denitrogenation (as described in the introduction) may permit earlier onset of symptoms (2), and thus increase incidence as observed during a two-hour period. Again if rapid ascent, per se, decreases incidence, then this effect would be greater in the 10,000 feet runs.

The reduction in symptoms in the flights at 27,500 feet was small and much less than that following the stays at 10,000 feet and 20,000 feet. Since the alveolar nitrogen tension was lowest in the 27,500 feet flights, it must be concluded that the high average symptom score in these flights as compared to that in the 10,000 feet and 20,000 feet flights was caused by bubble formation and thus, interference with denitrogenation.

Although the difference between the reduction of symptoms in the 10,000 feet and 20,000 feet flights is slight, it assumes more importance when considered in conjunction with the fact that the alveolar nitrogen tensions were greater in the 10,000 feet flights. In other words it appears likely that bubble formation at 20,000 feet has definitely interfered with denitrogenation.

These results appear to be of significance in pressurized cabin flight. They show that considerable protection against decompression sickness at 35,000 feet is provided by previous flight for one hour at 20,000 feet with standard oxygen supply. This protection is somewhat greater if the previous flight is made at 10,000 feet with considerable artificial oxygen supply and is much less if made at 27,500 feet with very high oxygen supply. Therefore, in order to minimize the chances of decompression sickness following pressure cabin puncture, the cabin should be pressurized to at least 20,000 feet and to a lower altitude if increased oxygen can be supplied. The interference of bubble formation with denitrogenation is thus apparently avoided.

The results may be of greater interest in connection with long bombing flights in which it is possible to fly at a moderate altitude some considerable period prior to ascent to high altitude. Circumstances such as the presence of a strong fighter escort, absence of anti-aircraft fire,

or flight over controlled waters might permit this procedure. The only condition in this investigation not applicable to this situation is the rapid rate of ascent employed. It is believed, however, that this is of minor importance.

The results in general, emphasize the value of short periods of denitrogenation in providing protection from decompression sickness. Since one hour at 10,000 feet with considerable nitrogen tension reduced the symptom score to 26% of that of controls it is reasonable to conclude that 100% oxygen at this altitude or at ground level might provide even better prophylaxis.

It should be emphasized that the 33 men used in this study were chosen for their high susceptibility from about 275 aircrew trainees. The protection provided by such denitrogenation at 20,000 feet applied to men who develop symptoms only occasionally, might be quite complete, since it is believed these men denitrogenate faster. For example, the procedure would be expected to give complete protection to men who are at present being selected in the R.C.A.F. for their high resistance to decompression sickness.

The reduction in symptom score following the one-hour stays at 10,000 feet, viz. to 26% of that of controls, is similar to that obtained by Gibson and Manning (3) and Gibson (4) who obtained reductions to 21% and 28% respectively of that of controls in their procedure, applying the same scoring technique. The procedure employed by these workers was the inhalation of approximately pure oxygen for 8 hours followed by 5 hours exposure to air prior to ascent to 35,000 feet.

SUMMARY AND CONCLUSIONS

1. Thirty-three men in a total of 360 man-runs were given one-hour flights at 10,000, 20,000 or 27,500 feet prior to rapid ascent to 35,000 feet and the incidence of decompression sickness was compared with that of controls. The oxygen supply in litors (N.T.P.) per minute was 4.2, 2.6, 3.5 and 4.5 at 10,000, 20,000, 27,500 and 35,000 feet respectively.

2. The incidence of decompression sickness as represented by an average symptom score was reduced to 26%, 37% and 73% of that of controls, by levelling off for an hour at 10,000 feet, 20,000 feet and 27,500 feet respectively, prior to ascent to 35,000 feet. The man-runs with moderate or

severe symptoms were reduced from 45% in controls to 20% and 12% following the flights at 20,000 and 10,000 feet respectively, and from 40% in controls to 28% following flights at 27,500 feet.

3. It is believed that the greater reduction in symptoms following the 10,000 and 20,000 feet stepwise ascents as compared with that following the 27,500 feet ascents is due to retardation of denitrogenation by the formation of bubbles at the latter altitude. Because of the slightly higher symptom score in the 20,000 feet flights as compared with the 10,000 feet flights, in spite of a higher alveolar nitrogen tension at the latter altitude, it would appear that there is also some interference with denitrogenation by bubble formation at 20,000 feet.

4. Maximal rate of denitrogenation with minimal oxygen administration would therefore appear to be provided by denitrogenation at an altitude somewhat less than 20,000 feet.

5. Recognition of the efficiency of denitrogenation during flights and the effect of "silent bubble" formation in decreasing it, appears warranted under the following operational conditions.

(a) High altitude flight preceded by periods of flight at low or moderate altitude.

(b) High altitude flight in pressurised cabin aircraft.

6. These results suggest that the prophylactic value of short periods of denitrogenation, immediately prior to ascent, warrants consideration.

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Author - A. M. Fraser, Squadron Leader.

APPENDIX A

THE SCORING OF SEVERITY OF DECOMPRESSION SICKNESS.

Introduction

It is realised that a system of scoring the severity of decompression sickness may be useful for investigative work and yet be unreliable in the categorization of men for operational duties. In such work as the evaluation of the effect of a drug or other factor on decompression sickness, it is felt that the symptom score should be related, as closely as possible, to etiology, rather than to the degree of danger which that symptom may produce in operations, for example. In this connection there would appear to be potential value in the suggestion that symptoms be scored in direct proportion to the degree of descent necessary to relieve them. However, the application of this would require further investigation.

The following factors are recognized and weighted: (1) Severity of symptoms; (2) Time of onset, and duration of symptoms; (3) Acuteness of onset of moderate or severe symptoms.

Multiplicity of symptoms is not scored because it would add to the complexity, and probably increase the accuracy of the score very little. The score of the severest grade of symptom only, is recognized and scored in the case of multiple symptoms. No significance is attached to location of symptoms; this factor would be important in scoring for operational duties.

Severity of Symptoms

Degree of severity of symptoms is recorded in the usual way, a mild symptom being one not interfering with function; a moderate, one which interferes with function, but is tolerable; and a severe symptom, one which is intolerable. All types of symptoms are recorded in this way. If a symptom is accompanied by systemic effects it is scored as a severe symptom, but no more, since probably most severe symptoms, if permitted to progress, would result in such a condition. It is suggested that the score of mild, moderate and severe symptoms be weighted in the ratio of 1:3:5. It is judged that this ration represents approximately the relative significance of the 3 degrees of symptoms. No distinction is made between moderate pain requiring descent and moderate pain not requiring descent. If descent is necessary then either the pain is intolerable, or systemic symptoms are present, and therefore in both cases the symptom should be recorded and scored as severe. All types of symptoms are scored in the same way.

It is emphasized that symptoms only and not signs are recorded in this system. That is, only the effects of decompression which cause acute discomfort or disability are included. A rash, which is a sign in the strict sense, would be neglected in the scheme. Even though such a sign may be considered an undesirable manifestation, it occurs so rarely that it would add little to the value of scoring in investigative work.

Time of Onset and Duration of Symptom

The symptom score is estimated as being directly proportional to

the time which it is present. This recognizes both factors of time of onset and duration. A period of three hours has been adopted as the basis for scoring. In other words, if a subject loses consciousness because of severe pain in one hour, he is scored on the assumption that the pain would remain severe until the end of the third hour. Again, if a flight lasted only two hours, the degree of severity of a symptom at that time is assumed to continue until the end of the third hour, and so on. The rationale for the adoption of this three-hour period is as follows.

It has been found that practically all symptoms begin during the first three hours of an exposure. Radiological studies by Evelyn of free gas in the joints also show that the bubbles reached a maximal size in about three hours. On theoretical grounds too, Bazett et al, have arrived at the conclusion that if a subject escapes symptoms for three hours at 35,000 feet, he has been able to denitrogenate to a nitrogen tension lower than that which they calculate is necessary to produce symptoms.

This method of scoring symptoms on the basis of time from onset to the end of a total exposure of three hours may be criticized because this adopted period is partly theoretical, and may vary considerably with individuals. There would appear, however, to be greater objections to the use of an alternative method of basing the score on the time from the beginning of the exposure, to onset of symptoms irrespective of the length of the exposure. In a long exposure of 12 hours, for example, a resistant man would receive four times as great a score as one who completed a three-hour exposure, by the latter method, although they may be of equal resistance; freedom from symptoms during the latter part of a long exposure is of little significance because of the reasons stated above. Again the latter method would not provide for the scoring of regression of symptoms. Finally it would not be possible to weight the score of an individual developing symptoms suddenly near the beginning of an exposure. (See below.)

Acuteness of Onset of Symptom

It is agreed that the sudden onset of moderate or severe degree of symptom justifies extra weighting. It is realised that in operations the sudden onset of severe pain may be many times more important than that of a pain with a gradual onset, because of the increased danger of loss of control of the craft or of vulnerability to enemy action. Weighting of this quality for investigative work is believed to be less important. Keeping in mind the cause of the symptom, it is suggested that acuteness of onset be recognized by assuming that all severe symptoms are preceded by one-half hour of moderate degree and one-half hour of mild degree of symptoms; similarly it would be assumed that all moderate symptoms are preceded by one-half hour of mild symptoms. If severe and moderate symptoms are, however, preceded by milder degrees of symptoms long enough to make the symptom score greater than that obtained using the above assumptions regarding onset, then that greater score would be adopted. These periods were chosen because experience has shown that they are reasonable periods in which such increases in severity may take place, and are used even though a severe symptom is present as soon as the maximal altitude is reached. If a symptom disappears and then reappears and becomes suddenly severe, the weighting for acuteness of onset of the latter symptom is calculated independently of the former symptom, although the score of the former symptom is included in the total score.

Calculation of Score

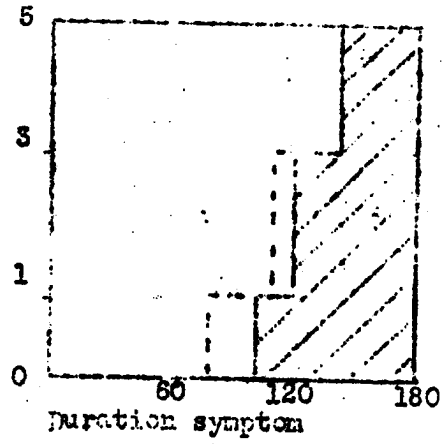
The symptom score is calculated as the product of the severity weighting (1, 3 or 5) and the duration of the symptoms in minutes. If moderate or severe symptoms have a sudden onset the following scores are added (see last section).

Sudden severe symptoms $-(30 \times 1) + (30 \times 3) = 120$

Sudden moderate symptoms $-(30 \times 1) = 30$

Then total sympton scores before time of onset of severe or moderate degrees of symptoms are less than 120 and 30 respectively, then these symptoms are recognized as having a sudden onset and these quantities are added as described above. If, however, the previous scores are greater than these quantities, then these actual larger scores are used.

The illustrations below demonstrate the scoring method suggested.



Dotted lines = extra score for sudden onset.

(a) Mild symptom beginning at 100 mins.

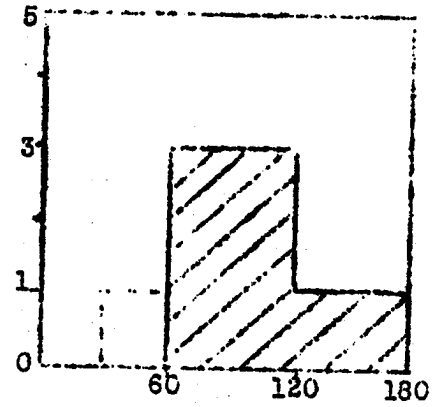
Moderate " " " 120 "

Severe " " " 140 "

Separate scores are 1 x 20, 3 x 20 and 40 x 5 = 20, 60, and 200. 20 + 60 = 80

Since this is less than 120, the onset is sudden and 120 is added to 200.

Total score = 200 + 120 = 320.

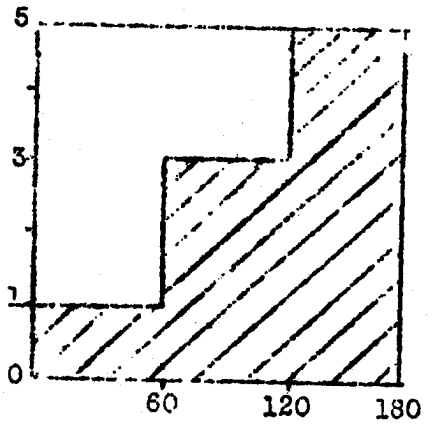


(b) Moderate symptom at 60 minutes.

Mild " " 120 "

Separate scores are (60 x 3) + 30 (sudden onset) + (60 x 1).

Total score = 180 + 30 + 60 = 270



(c) Mild symptom beginning at 0 minutes.

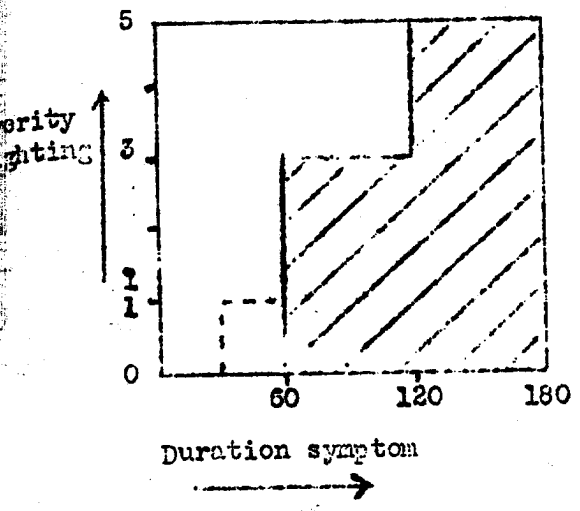
Moderate " " " 60 "

Severe " " "120 "

Separate scores are 60 x 1, 60 x 3 and 60 x 5 = 60, 180, and 300.

60 is greater than 30, and is therefore adopted as score for mild stage. 60 + 180 = 240 which is greater than 120.

Total score is therefore 240 + 300 = 540.



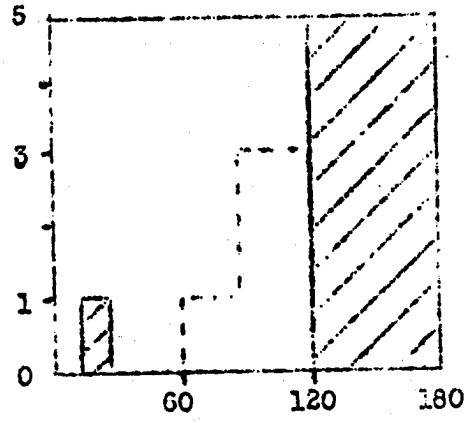
(d) Moderate symptoms beginning at 60 mins.

Severe " " " 120 "

Separate scores = (60 x 3) ÷ 30 (sudden onset)
÷ (60 x 5).

= 210 + 300.

210 is greater than 120, therefore final score = 210 + 300 = 510.



(e) Mild symptoms beginning at 10 minutes.

No symptoms at 20 minutes.

Severe symptoms at 120 minutes.

Separate scores = 10 x 1, 60 x 5, 120
(sudden onset weighting)

Total Score = 10 + 300 + 120 = 430.

It would not matter greatly whether the area above or below the severity tracing were used as the score. If one area is known, the other may be determined by subtracting the known from 900. The area above would indicate degree of resistance, whereas the area below would indicate degree of susceptibility. A disadvantage in using the upper areas is that the value would be negative in rare cases when severe symptoms occurred at the beginning of a flight.

APPENDIX B

Subject Number	(Control) Two Hours at 35,000 Feet			One Hour at 20,000 Feet & 2 Hours at 35,000 Feet			One Hour at 10,000 Feet & Two Hours at 35,000 Feet.		
	Date	Symptom Score	Average Score	Date	Symptom Score	Average Score	Date	Symptom Score	Average Score
1	19-9	309		17-9	10		18-9	0	
	22-9	284	296	20-9	150	80	21-9	0	0
2	19-9	485		17-9	210		18-9	0	
	22-9	126	305	20-9	0	105	21-9	0	0
3	19-9	145		17-9	105		18-9	0	
	22-9	0	72	20-9	0	52	21-9	0	0
4	19-9	50		17-9	0		18-9	0	
	22-9	0	25	20-9	0	0	21-9	0	0
5	19-9	0		20-9	7		18-9	80	
	22-9	85	42	17-9	354	180	21-9	0	40
6	28-9	49		29-9	0		30-9	0	0
	1-10	0	24	2-10	84	42			
7	28-9	123		29-9	0		30-7	0	
	1-10	0		2-10	0		3-10	0	
	4-10	0	41	5-10	0	0	6-10	0	0
8	26-9	645		29-9	0		30-9	75	
	1-10	975		2-10	0		3-10	122	
	4-10	875	832	5-10	0	0	6-10	0	66
9	28-9	530		29-9	0		30-9	0	
	1-10	432		2-10	0		3-10	0	
	4-10	0	321	5-10	750	250	6-10	0	0
10	25-9	465		29-9	0		30-9	70	
	1-10	153		2-10	381		3-10	130	
	4-10	385	334	5-10	148	176	6-10	405	202
11	26-9	955		29-9	63		30-9	0	
	1-10	700		2-10	0	31	3-10	770	257
	4-10	186	614				6-10	0	
12	6-11	720		8-11	294		10-11	69	
	12-11	312		18-11	282	192	20-11	0	23
	16-11	86	378	23-11	0		24-11	0	
	22-11	203							
13	5-11	885		7-11	710		8-11	0	
	11-11	470		17-11	610	440	19-11	0	280
	16-11	0	562	23-11	0		24-11	840	
	21-11	895							

APPENDIX B (i)

	(Control) Two Hours at 35,000 Feet			One Hour at 20,000 Feet Two Hours at 35,000 Feet			One Hour at 10,000 Feet Two Hours at 35,000 Feet		
Subject Number	Date	Symptom Score	Average Score	Date	Symptom Score	Average Score	Date	Symptom Score	Average Score
14	6/11	655		8/11	0	0	10/11	92	
	12/11	0		17/11	0		19/11	0	
	16/11	30		23/11	0		24/11	0	31
	21/11	1020	426						
15	6/11	255		8/11	0		10/11	0	
	12/11	0		17/11	0		20/11	0	
	22/11	0	85	23/11	0	0	24/11	70	23
13	6/11	685		8/11	393		10/11	220	
	12/11	690		18/11	0	131	20/11	0	90
	16/11	0		23-11	0				
	22/11	495	467						
17	5/11	0		7/11	0		9/11	0	
	11/11	24		17/11	0		19/11	0	
	16/11	0		23/11	146	49	24/11	0	0
	21/11	0	6						
18	6/11	895		8/11	0		16/11	0	
	16/11	0		18/11	0		26/11	0	
	22/11	0	298	23/11	81	27	24/11	0	0
19	6/11	590		8/11	0		10/11	0	
	12/11	65		18/11	0		20/11	0	
	16/11	0	190	25/11	0	0	24/11	0	0
20	5/11	342		9/11	444		7/11	257	
	11/11	354		17/11	102		19/11	0	
	16/11	30		23/11	9	184	24/11	0	86
	21/11	143	217						
21	5/11	0		7/11	138		9/11	715	
	11/11	0		17/11	0		19/11	0	
	16/11	0		23/11	0	46	24/11	0	238
	21/11	0	0						
22	5/11	0		7/11	102		9/11	405	
	11/11	570		17/11	300		19/11	90	
	16/11	0		23/11	30	144	24/11	20	171
	21/11	356	231						
Total Average Scores			5766			2129			1507
Average Score			262			97			68
% of Control Score			100%			37%			26%
Number of Man-Runs With No Symptoms			24			34			42
% of Man-Runs With No Symptoms			35%			58%			71%
# of Man-Runs With Mild Symptoms Only			14			13			10
% of Man-Runs With Mild Symptoms Only			20%			22%			17%
# of Man-Runs With Moderate or Severe Symptoms			31			12			7
% of Man-Runs With Moderate or Severe Symptoms			45%			20%			12%

APPENDIX C

Effect of One Hour Stays at 27,500 Feet on Symptom Score.

	(Control) Two Hours at 35,000 Feet.			One Hour at 27,500 Feet - - - Two Hours at 35,000 Feet		
Subject Number	Date	Symptom Score	Average Score	Date	Symptom Score	Average Score
12	29-11	690		1-12	0	
	3-12	0		2-12	0	
	6-12	0	230	4-12	0	
				5-12	0	0
13	30-11	20		1-12	775	
	3-12	0		2-12	0	
	6-12	890	303	4-12	735	
				5-12	730	560
14	30-11	0		1-12	0	
	3-12	0		2-12	0	
	6-12	0	0	4-12	0	0
15	30-11	135		1-12	368	
	3-12	0		2-12	0	
	6-12	0	45	5-12	0	123
16	30-11	520		1-12	0	
	3-12	0		2-12	0	
	6-12	0	173	4-12	0	
				5-12	0	0
17	30-11	0		1-12	0	
	3-12	0		2-12	0	
	6-12	0	0	5-12	0	0
18	30-11	323		1-12	0	
	3-12	0		2-12	0	
	6-12	255	193	4-12	0	
				5-12	324	81
19	30-11	185		1-12	0	
	3-12	5		2-12	0	
	6-12	0	63	4-12	0	
				5-12	0	0
20	30-11	0		1-12	0	
	3-12	0		2-12	0	
	6-12	336	112	4-12	0	
				5-12	0	0

APPENDIX C (i)

Effect of One Hour Stays at 27,500 Feet on Symptom Score.

	(Control) Two Hours at 35,000 Feet			One Hour at 27,500 Feet Two Hours at 35,000 Feet		
Subject Number	Date	Symptom Score	Average Score	Date	Symptom Score	Average Score
21	30-11	0		1-12	0	
	3-12	0		2-12	0	
	6-12	0	0	4-12	0	
				5-12	0	0
22	30-11	0		1-12	0	
	3-12	970		2-12	10	
	6-12	0	323	4-12	0	
				5-12	0	2
23	13-1	136		14-1	0	
	16-1	0		15-1	121	
	19-1	0		17-1	0	
	22-1	0	34	18-1	0	
				20-1	0	
				21-1	0	20
24	13-1	65		14-1	66	
	16-1	88		15-1	0	
	19-1	145		17-1	1020	
	22-1	0	75	18-1	23	
				20-1	11	
				21-1	0	187
25	13-1	330		14-1	163	
	16-1	90		15-1	28	
	19-1	0		18-1	0	
	22-1	0	105	20-1	0	
				21-1	0	38
26	16-1	985		15-1	0	
	19-1	790		17-1	760	
	22-1	487	754	18-1	845	
				20-1	0	
				21-1	0	321
27	13-1	1005		14-1	1020	
	16-1	960		15-1	200	
	19-1	1020		17-1	875	
	22-1	685	917	18-1	1020	
				20-1	80	689
				21-1	940	
28	13-1	279		14-1	0	
	16-1	521		15-1	0	
	19-1	865		17-1	865	
	22-1	0	416	18-1	765	
				20-1	0	329
				21-1	345	

APPENDIX C (ii)

Effect of One-Hour Stays at 27,500 Feet on Symptom Score

	(Control) Two Hours at 35,000 Feet			One Hour at 27,500 Feet Two Hours at 35,000 Feet		
Subject Number	Date	Symptom Score	Average Score	Date	Symptom Score	Average Score
29	13/1	790		14/1	0	
	16/1	905		15/1	940	
	19/1	785		17/1	0	
	22/1	815	824	18/1	955	
				20/1	735	
				21/1	915	591
30	13/1	20		14/1	0	
	16/1	32		15/1	4	
	19/1	0		17/1	12	
	22/1	0	13	18/1	0	
				20/1	0	
				21/1	0	3
31	13/1	288		14/1	0	
	16/1	865		15/1	0	
	19/1	36		17/1	680	
	22/1	0	297	18/1	65	
				20/1	0	149
32	13/1	207		14/1	427	
	16/1	129	168	15/1	158	
				17/1	438	
				18/1	293	334
33	13/1	0		14/1	0	
	15/1	445		15/1	0	
	22/1	0	148	17/1	650	
				21/1	810	365
Total Average Scores			5198			3812
Average Score			236			173
% of Control Score			100%			73%
# of Man-Runs With No Symptoms			34			62
% of Man-Runs With No Symptoms			46%			62%
# of Man-Runs With Mild Symptoms Only			10			10
% of Man-Runs With Mild Symptoms Only			14%			9%
# of Man-Runs With Moderate or Severe Symptoms			29			28
% of Man-Runs With Moderate or Severe Symptoms			40%			28%